Intl. J. Food. Ferment. Technol. 6(2): 207-217, December, 2016

DOI: 10.5958/2277-9396.2016.00044.1

REVIEW PAPER

Fermentation and its Application in Vegetable Preservation: A Review

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Paper No.: 130 Received: 12 June 2016 Accepted: 10 Dec. 2016

ABSTRACT

Fresh vegetables have a very short shelf-life since these are subjected to physiological and rapid microbial spoilage and in some cases contamination by pathogens also. Processing or modification of raw foods by using food processing methods and techniques is needed to meet the challenges of food security and safety, nutrition demand and availability of food. Fermentation is one of the important methods of preservation of vegetables. It is one of the oldest means of food preservation and reduces the risk of food borne diseases and food spoilage. Sauerkraut is a traditional fermented vegetable product and is prepared by the fermenting salted cabbage by naturally occurring lactic acid bacteria. Kimchi is another such products made by lactic fermentation of radish and other vegetables. Carrot when fermented similarly gives 'kangi', a beverage very popular in several parts of India. In this review is focussed on the lactic acid fermentation of vegetables.

Keywords: Fermentation, food, spoilage, vegetable, microbes, lactic acid bacteria, sauerkraut, preservation

Fermentation is a metabolic process that converts sugar to acids, gases, or alcohol by the microorganisms or their enzyme. It occurs in yeast and bacteria, and also in oxygen-starved muscle cells, as in the case of lactic acid fermentation. Fermentation is also used more broadly to refer to the bulk growth of microorganisms on a growth medium, often with the goal of producing a specific chemical product. Louis Pasteur is often remembered for his insights into fermentation and its microbial causes. Adams (1990) described fermentation as a form of energy-yielding microbial metabolism in which an organic substrate, usually a carbohydrate, is incompletely oxidized and an organic carbohydrate acts as the electron acceptor. Thus, fermentation is a biological activity where sugar is converted into alcohol, catalyzed by microorganism or their involve its conservation into enzyme. Glucose is considered as a typical substrate for fermentation as it is most widely distributed sugar and the most bacteria and yeast can utilize it. The initial step in the metabolism of most other substrates intermediate products of glycolytic pathway. Pyruvic acid, during fermentation, instead of getting converted into acetyl CoA entering into the end product of fermentation thus play a key role in fermentation (Lehninger, 1990).

IMPORTANCE OF VEGETABLES IN DAILY DIET

Vegetables and fruits are rich sources of nutrients, including vitamins; trace minerals, dietary fiber and many other required for growth and development of individual. These phytochemicals can have complementary and overlapping mechanisms of action, including modulation of detoxification enzymes, stimulation of the immune system, reduction of platelet aggregation, modulation of cholesterol synthesis, hormone metabolism, reduction of blood pressure, antioxidant, antibacterial and antiviral effects (Dias, 2012, Lobo, 2010 and Dewanto, 2002). Vegetables have protective role in the prevention of coronary heart disease, chronic obstructive pulmonary diseases, cataract formation, diverticulosis *etc.* (Table 1). Many compounds found in vegetable have properties to cure or inhabit cancer even HIV. Increased consumption of a wide variety of vegetables, in particular, dark-green leafy, cruciferous, cucurbits, solanaceous vegetable *etc*. (Table 2 and Fig. 1). Continued attention to increasing vegetables consumption is a practical and important way to optimize nutrition to reduce disease risk and maximum good health (Ann *et al.,* 2000).

EXPERIMENTAL EVIDENCE OF HEALTHFUL EFFECTS

These effects have been examined primarily in animal and cell-culture models, experimental dietary studies in humans have also shown the capacity of vegetables and fruits, and their constituents to modulate some of these potential disease-preventive mechanisms (Lampe, 1997). Southon (2000) conducted a study on humans in Ireland, Northern Ireland, Spain, France and the Netherlands. Oxidative and antioxidant status, vegetables and fruits consumption and carotenoid intake of volunteers from different countries were compared and protective effects of carotenoid-rich foods against LDL and DNA oxidative damage was determined. Results demonstrated that carotenoid supplementation did not increase LDL oxidation resistance. Similarly, LDL oxidation resistance doesn't increase with increased consumption of carotenoid-rich fruits and vegetables. Higher plasma concentration of total and specific carotenoids was associated with lower DNA damage and higher repair activity. Phytochemical extract of vegetables exhibited strong antioxidant and antiproliferative activities and that major part of total antioxidant activity was from the combination of phytochemicals. Consumption of 5 to 10 serving of a wide variety of fruits and vegetables daily shows the reduced risk of chronic disorder and can meet their nutrient requirements for optimum health (Liu, 2004; Slavin and Lloyd, 2102 and Dias, 2012).

Table 1: Vegetables and its health benefit

Vegetables	Health benefit
Asparagus	Potentially prevent high blood pressure, heart-related diseases cognitive decline, bestowing it with anti-aging properties. Asparagus is packed with antioxidants, which neutralize cell-damaging free radicals.
Beets	Oxygenate blood and enhance exercise performance.
Bell peppers	Keep teeth, gums, eyes and skin healthy.
Broccoli	Improve rough skin and also having Anti-cancer property.
Cabbage	Antibacterial, antioxidant, and an anti-inflammatory.
Carrots	Protect the body from cancer, cardiac disease, and cataract and macular degeneration.
Celery	Help promote healthy blood pressure, strengthen joints, bones, arteries, and connective tissues.
Onions	Red onions can also help to lower blood sugar levels, due to their trace amounts of quercetin.
Radishes	Antiviral, a digestive, and very detoxifying. A god source of potassium and iron. Anti-mucus and great for colds or after having too much dairy.

Enrichment of traditional food with green leafy vegetable for iron security and appreciably also studied. Vegetables are universally promoted as healthy. The Dietary Guidelines for Americans 2010 recommend one-half of the plate as fruits and vegetables. Fruits and vegetables include a diverse group of plant foods that vary greatly in content of energy and nutrients (Karva, 2008). Additionally, vegetables supply dietary fiber, and fiber intake is linked to poorer incidence of cardiovascular disease and obesity (Slavin and Lloyd 2012).

Table 2: Phyto-nutriceuticals in vegetables

Family	Name of the vegetables	Phyto-nutriceuticals
Apiaceae	Celery and parsley	flavonoid apigenin and vitamin E
	Carrots	kaempferol, quercetin, and luteolin
Compositae	"Lollo Rosso", a red cultivar of lettuce	quercetin, flavonoids, and tocopherols.
Cucurbitaceae	Bitter gourd	Momorcharin and Momorcidin
Solanaceous	Tomato	carotenoids consisting of 60% to 64% lycopene, phytoene, neurosporene, and carotenes

Source: Clinton, 1998 and Crozier, 2000

Each vegetable group contains a unique combination and amount of certain phyto-nutriceuticals, which distinguishes them from other groups and vegetables within their own group. In the daily diet vegetables have been strongly associated with improvement of gastrointestinal health, good vision and reduced risk of heart disease, stroke, chronic diseases such as diabetes and some forms of cancer (Dias, 2012).

NEED FOR THE PROCESSING OF VEGETABLES

At the time of harvesting, vegetables generally contain high amount of moisture which makes these produce highly perishable. Improper storage facilities and lack of proper marketing avenues lead to the spoilage of large quantity of vegetables produced in the country. Drying is one of the most widely spread preservation techniques. Dehydration substantially increases shelf-life of the product, lowers transportation, handling and storage cost. It provides consistent product, an important modern marketing requirement (Amin and Bhatia, 1962). Heat treatment is again a very important process but it alters the natural healthy enzymes, fatty acids, vitamins and minerals. In comparison to raw and unprocessed foods processed foods are usually safer, durable and with high level of bioactivity of nutrients. The advancement in food processing methods and techniques is necessary to meet the challenges of food security and safety, nutrition demand and availability of food at the global level (Satyanarayana *et al.,* 2012).

FERMENTATION TECHNOLOGY

Fermentation is an easy and mainly household-level technique but it has industrial use also. It is one such technology that has been developed indigenously for a wide range of food commodities (Hesseltine, 1981). These include cereals, legumes, root crops, fruits, vegetables and dairy products. As a unit operation in food processing, fermentation offers a large number of advantages, including food preservation, improved food safety, enhanced flavor and acceptability, increased variety in the diet, improved nutritional value, reduction in anti-nutritional compounds and in some cases, improved functional properties also (Westby *et al.,* 1997).

Lactic acid fermentation

Lactic acid fermentation is the most important technique of presentation so far vegetables fermentation are concerned. Lactic acid fermentation is a biological process by which sugars such as glucose, fructose, sucrose etc. are converted into cellular energy and the metabolic byproduct lactate by lactic acid bacteria. The lactic acid bacteria (Table 3) area group of Gram positive bacteria, non-respiring, non-spore forming, cocci or rods. Lactate dehydrogenase catalyzes the inter-conversion of pyruvate and lactate with concomitant inter-conversion of NADH and NAD+. Different microorganisms (LAB) associated with different products are listed in Table 4.

Two type of Lactic acid fermentation exist that is homolactic fermentation and heterolactic fermentation. In homolactic fermentation, one molecule of glucose is converted into two molecules of lactic acid. Again in case of heterolactic fermentation, one molecule of glucose is converted into one molecule of lactic acid, one molecule of ethanol, and one molecule of carbon dioxide (Axelsson, 1998).

Before lactic acid fermentation can occur, the molecule of glucose must be split into two molecules of pyruvate. This process is called glycolysis.

Table 3: Major lactic acid bacteria involved lactic acid

Homofermenter Facultative	Homofermenter Obligate	Heterofermenter
Enterococcus faecium	*Lactobacillus bavaricus*	*Lactobacillus brevis*
Enterococcus faecalis	*Lactobacillus casei*	*Lactobacillus buchneri*
Lactobacillus acidophilus	*Lactobacillus coryniformis*	*Lactobacillus cellobiosus*
Lactobacillus lactis	*Lactobacillus curvatus*	*Lactobacillus confuses*
Lactobacillus delbrueckii	*Lactobacillus plantarum*	*Lactobacillus coprophilus*
Lactobacillus salivarius	*Lactobacillus sake*	*Lactobacillus fermentatum*
Pediococcus pentocacus		*Lactobacillus sanfrancisco*
Streptococcus thermophilus		*Leuconostoc dextranicum*
Pediococcus acidilactici		*Leuconostoc mesenteroides*
Pedicoccus damnosus		*Leuconostoc paramesenteroides*

Source: Beuchat, 1995.

BENEFITS OF FERMENTATION

In general, significant increase in the soluble fraction of a food is observed during fermentation. The quantity as well as quality of the food proteins as expressed by biological value and often the content of water soluble vitamins is generally increased, while the anti-nutritional factors decline during fermentation (Paredes-Lopez and Harry, 1988). Fermentation results in a lower proportion of dry matter in the food and the concentrations of vitamins, minerals and protein appear to increase when measured on a dry weight basis (Adams, 1990). Riat and Sadana (2009) reported that fermentation caused a significant reduction in phytate content and also increase the availability of Zinc, Calcium and Iron content. The phytate: Zn, phytate × Ca:Zn molar ratio of fermented and processed products also become lower than that of the raw foods. Thus indicating that bioavailability of Zinc, Calcium and Iron is more from fermented product than from raw foods.

FACTORS INFLUENCING FERMENTATION PROCESS

Various factor influence the fermentation directly or indirecty starting from moisture to pH, temperature etc. Moisture requirements are affected by nutrients, oxygen, temperature and other factors.

Moisture water activity

The values of water activity (a_w) ranged from 0 to 1. A great increase in salt may exert a greater osmotic pressure outside the microbial cell and result in cell degradation. The solute used to lower the a_w affected the growth of microorganisms. The a_w is an index of the availability of water for chemical reactions and microbial growth (Banwart, 1989).

pH

Success of fermentation processes considerably depends on pH and it is also an indicator of fermentation process. Blanc (1996) observed the higher pH (6-7) of the culture at the beginning of the incubation period and dropped quickly as a result of acid formation. Pundir and Jain, (2010) observed pH of sauerkraut brine ranged between 3.0-4.0 and showed the decreasing trend from the day of preparation up to 120th day of storage. Titrable acidity is a measure of the amount of acid present in a solution (Joshi and Sharma, 2012).

Temperature

Temperature is one of the most important environmental factors that regulates the growth of microorganisms. The cell size, metabolic product such as pigments and toxins, nutritional requirement, enzymatic reactions and the chemical composition of cell also influenced by environmental temperature (Pederson, 1979). The quality of sauerkraut is dependent on the growth of the lactic acid bacterium. At higher temperatures, the growth of the homo-fermentor *Lactobacillus plantarum* is favored altering sauerkraut quality. Fermentation at higher temperatures will often result in a low concentration of acetic acid due to limited growth of hetero-fermentative LAB.

Yeast spoilage may occur with low concentrations of carbon dioxide and sauerkraut will have a darker color and poor shelf-life. Sauerkraut fermented at temperatures of 13 to 18°C will be superior in quality to that fermented at 24 °C and above, since the hetero-fermentative LAB grows better at lower temperatures (Fleming *et al.,* 1985). Temperature is the primary environmental factors which influence the progress of the two main LAB groups and the quality of sauerkraut. 18°C is the ideal temperature for sauerkraut production (Fleming *et al.,* 1991). Holzapfel *et al.* (2008) demonstrated that temperature plays a key role in sauerkraut fermentation. The ideal temperature is between 15 and 20°C. Lower temperatures will hamper the start of fermentation and higher temperatures can cause an accelerated acid production, which can lead to products with atypical flavor.

Salt

Salt has the capability to change the osmotic pressure. Deferent microbes have their own comfort zone of osmotic pressure. Alteration of the comfort zone effects the normal growth, development and the efficiency of the microbes. Pederson and Albury (1969) demonstrated that low salt concentration is more advantageous to the growth of hetero-fermentative *Leuconostoc mesenteroides* since this microorganism is more salt sensitive than other LAB. High salt concentration favors the growth of homo-fermentative lactic acid bacteria but inhibits the growth of hetero-fermentative LAB resulting in a predominance of homo-fermentative species that produce little carbon dioxide essential for flushing out entrapped air among cabbage shreds, so yeast growth might become more prevalent. Salt withdraws water and nutrients from the cabbage tissue. The nutrients serve as substrates for growth of lactic acid bacteria. Salt together with acid inhibits growth of undesirable microorganisms and delays enzymatic softening of the cabbage. It is generally known that insufficient salt results in softening of sauerkraut and yields products that lack desirable flavor. It has been determined to be 2 to 3% as the proper salt concentration for the fermentation of cabbage. Salt concentration effects the growth of the four major LAB species involved in sauerkraut fermentation (Fleming *et al.,* 1985). Salt is one of the most critical points in the production of sauerkraut. Salt is needed for microbial growth and also for the sensory properties of the final product. Sodium chloride (salt) causes the osmotic withdrawal of water from the cabbage cells, of which the emerging liquid fills up the space between pieces of cabbage and supports the development of anaerobic conditions, which comprise the selective basis for the lactic acid fermentation. The amount of salt added affects the microbial population. An increased amount limits the growth of undesirable microorganism and promotes the growth of desirable bacteria *i.e.* lactic acid bacteria (Holzapfel *et al.,* 2008). The ideal salt concentration for sauerkraut production is 2.0-2.25 per cent (w/w) respectively for shredded cabbage in the U.S. or 0.75-1.5% salt in German sauerkraut manufacture (Fleming *et al.,* 1991).

DEVELOPMENT OF VALUE ADDED PRODUCTS FROM VEGETABLES

Gundruk, *sinki* and *khalpi* are the fermented vegetable products of Sikkim. *Inziangsang* fermented leafy vegetable product of Nagaland and Manipur in India. It is observed that LAB comprising *Lactobacilli, pediococci* and *leuconostocs* were the predominant microorganisms present in viable numbers above 10^7 g^{-1} (Tamang *et al.*, 2005).

Sauerkraut is the traditional fermented cabbage product. It is produced by the fermentation of cut and salted cabbage by naturally occurring lactic acid bacteria (Johanningsmeier *et al.,* 2005). To prepare, outer green and dirty leaves are removed and cores of the heads are partly removed; cabbage is shredded to 0.7-2.2 millimeter wide strips; shredded cabbage is salted with 0.7 to 2.5 per cent sodium chloride; salted, shredded cabbage is placed into fermentation containers; fermentation takes place within a few hours and continues between seven days and several weeks (Holzapfel *et al.*, 2008).

Many Organism play a vital role in sauerkraut fermentation. It is initiated by *Leuconostoc mesenteroides,* a hetero-fermentative LAB, converting fermentable sugars of cabbage, which are primarily glucose and fructose in to lactic acid, mannitol, acetic acid, ethanol and carbon dioxide. *L. mesenteroides* typically dominates the early fermentation since it is present in larger numbers. Formation of lactic and acetic acids rapidly reduce the pH in the weakly buffered brine and inhibits the growth of undesirable microorganisms and activities of their enzymes, which may cause the cabbage to spoil and soften. Acetic acid produced by *L. mesenteroides* inhibits the growth of *Listeria monocytogenes* and most other pathogenic bacteria and increases the desirable sensory properties of the product (Mundt *et al.*, 1967; Mundt and Hammer, 1968; Stamer *et al.*, 1971 and Schleifer and Ludwig, 1995).

Sauerkraut fermentation is complex and involves many chemical, physical and microbiological factors that influence quality of the product. The fermentation can be broadly categorized into 2 stages, an initial hetero-fermentative (gaseous) stage, followed by a homo-fermentative stage. Pederson and Albury (1969) listed 5 species of lactic acid bacteria as important in the sauerkraut fermentation: *Streptococcus faecalis, Leuconostoc mesenteroides, Lactobacillus brevis, Pediococcus pentocaceus and Lactobacillus plantarum.* Changes in lactic acid bacterial flora throughout spontaneous fermentation of Chinese sauerkraut was studied and results showed that fermentation process was initiated by *Leuconostoc mesenteroides* sub sp. *mesenteroides,* followed by *Enterobacter faecalis, Lactobacillus lactis, L. zeae* and finally succeeded by *L. plantarum* and *L. case* (Xiong *et al.*, 2012 and Yu *et al.*, 2013). Xiong *et al.* (2014) isolated four lactic acid bacteria (LAB) strains, *Leuconostoc mesenteroides* NCU1426*, Lactococcus lactis* NCU1315*, Lactobacillus plantarum* NCU1121 and *Lactobacillus casei* NCU1222 from traditional and fermented Chinese sauerkraut.

Table 4: Microorganisms involved in different Fermented vegetables developed

Fermented Vegetables	Microorganisms involved
Bossam kimchi (Pickled cabbage kimchi)	*Lactobacillus plantarum, Lactobacillus brevis, Streptococcus faecalis, Leuconostoc mesenteroides, Pediococcus pentosaceus*
Pak-Gard-Dong	*Lactobacillus brevis, Pediococcus cerevisiae, Lactobacillus plantarum*
Gundruk	*Lactobacillus plantarum, Pediococcus pentosaceus*
Fermented fruit juices	*Lactobacillus casei*
Fermented vegetable juices	*Lactobacillus* strains
Sunki (Otaki turnip)	*Lactobacillus plantarum, Lactobacillus brevis, Bacillus coagulans*
Kawal (Sickle pod plant)	*Bacillus subtilis, Lactobacillus plantarum*

Source: Joshi and Sharma, 2012.

Pickled cucumbers are another fermented product that has been studied in detail and the process is known. The fermentation process is very similar to the sauerkraut process, only brine is used instead of dry salt. The washed cucumbers are placed in large tanks and salt brine (15 to 20%) is added.

Carrot yoghurt was by prepared blending milk with 5, 10, 15 and 20% carrot juice before fermentation. Chemical and microbiological qualities of yoghurt samples were investigated during storage at 4°C for three weeks. Results revealed an increase in acidity, decrease in soluble nitrogen or total nitrogen ratio and curd tension with increasing the quantity of carrot juice. High carrot juice suppressed the growth of mold and yeast, coliform organisms while *Lactobacillus bulgaricus* and *Streptococcus thermophillus* were not significantly affected. Yoghurt with 5, 10, 15 and 20% carrot juice showed a significant decrease

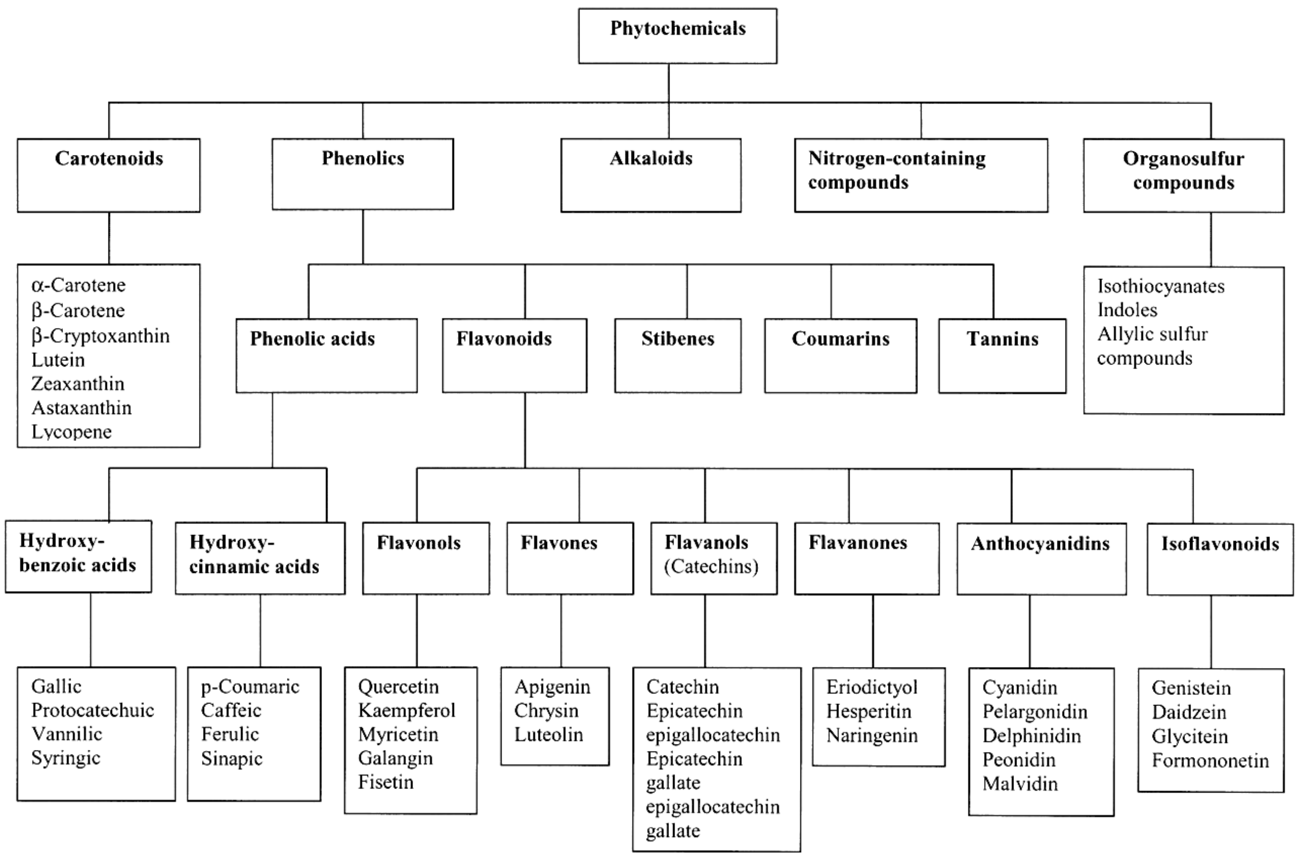

Fig. 1: Classification of phytochemicals found in different vegetables

Source: Liu, 2004

in aflatoxin M1 production, respectively (Aly *et al.*, 2004).

Sweet, white, and yellow storage onions in another study were used to produce sour onion by lactic acid fermentation. The onions were sliced to 0.3 cm thick; salt was added at 1.5, 2.0, and 2.5 g/100 g without or with sugar at 1.0 and 2.0 g/100 g. The sour onion had a tart acidic taste, characteristic of sauerkraut, with onion flavor but without the pungency of raw onions. (Roberts and Kidd (2005).

Sweet potato is an important root crop but having comparatively short self-life. To overcome this bottleneck, fermentation preservation could be a very profitable way. Sweet potato roots were pickled by lactic fermentation by brining the cut and blanched roots in common salt (NaCl, 2–10 %) solution and subsequently, inoculated with a strain of *Lactobacillus plantarum* (MTCC 1407) for 28 days. The treatment with 8% brine solution was found to be the most acceptable organo-leptically (Panda *et al.*, 2007).

Joshi *et al.* (2011) developed and evaluated the instant chutney mix prepared from fermented vegetables. The vegetables were fermented using sequential culture of lactic acid bacteria *viz.*, *Lactobacillu splantarum* (NCDC 020), *Pediococcus cerevisiae* (NCDC 038) and *Streptococcus lactis*var. *Diacetylactis* (NCDC 061). Different combinations of fermented vegetables *viz.*, carrot, radish and cucumber with an ardanaand amchoor powders were made separately and processedas per the routine practice. Different combinations of fermented vegetable powders + anardanaor amchoor powders (1:1) along with only amchoorand anardana powder based chutneys were prepared. The results revealed that titrable acidity of carrot, radish and cucumber based instant chutneys ranged from 0.72 to 1.24%. The ratio of fermented vegetable powders to the fruit powders influenced the titrable acidity, brix-acid ratio, pH and colour of the products.

SENSORY ACCEPTANCE OF VEGETABLE PRODUCTS

Acceptability of the any product is the ultimate and most important and to achieve the same sensory evolution is the most reliable method. Effect of blanching time, salt concentration and fermentation on texture of green beans was determined. Beans were blanched at 90 ºC for 1, 10 or 20 minutes and fermented with brine containing 3.08 and 4.6% salt. Sensory evaluation was carried out to assess the taste, texture and overall acceptability of the products. Results revealed that increase in blanching time improved the texture significantly. Significant decrease in shearing energy of the beans was observed in the first two days of fermentation and thereafter, there were no significant changes except for samples blanched for one minute. Beans blanched for 20 minutes and fermented with 1.2% salt brine were most acceptable (Mnkeni *et al.*, 1999).

Carrot yoghurt was prepared by blending milk with 5, 10, 15 and 20% carrot juice before fermentation. The sensory attributes of yoghurt samples were analyzed during refrigerated storage at 4°C for three weeks. The results showed that sensory scores increased especially for yoghurt samples with 15% carrot juice (Aly *et al.,* 2004). Ogunjobi *et al.* (2005) Irish Potato slices were fermented in 2.0 per cent brine solution under micro-aerophilic condition for few days at room temperature and organoleptic parameters were accessed through trained panelist. The results showed that fried fermented chips were more desirable and preferred to the unfermented control (Ogunjobi *et al.*, 2005). Sweet, white, and yellow storage onions was used for Lactic acid fermentation to produce sour onion and sensory evaluation was accessed through trained panelist. Results showed that the Lactic acid fermentation yellow storage sour onion was a favorable product with respect to color, texture and flavor (Roberts and Kidd, 2005)

Viander *et al.* (2003) reported that sauerkraut juice fermented with 0.5% mineral salt had better taste. Again mineral salt in combination with *Leuconostoc mesenteroides* had sauerkraut juice with good sensory and microbiological quality (Wiander and Ryhanen, 2005). Wiander and Palva (2011) also reported that sauerkraut juice fermented by using 0.8% mineral salt was found to have best sensory quality.

SHELF-LIFE AND STORAGE OF VEGETABLE PRODUCTS

Shelf-life of fermented product is an important aspect as the ultimate goal for fermentation is to increase the shelf-life. Fleming *et al.* (1983) conducted a study to determine problems associated with microbiological and product stability during storage of seven vegetables fermented with pH control to facilitate complete removal of fermentable sugar. The results showed that vegetable fermented by *Lactobacillus plantarum* with pH control were microbiologically stable during 12 months of storage in hermetically sealed jar at 24ºC provided all fermentable sugar were removed during fermentation and the products were stored at pH 3.8 or below.

Viander *et al.* (2003) studied the impact of low NaCl and mineral salt concentrations on the large-scale (430 kg) fermentation of white cabbage into sauerkraut and sauerkraut juice and their shelf-life was studied. It was found that the number of lactic acid bacteria decreased in sauerkraut juices during storage at 4ºC. Also the number of yeasts and moulds, enterobacteria, mesophilic and thermophilic spores decreased during storage. Pundir and Jain, (2010) conducted a study to determine the change in bacterial and fungal flora of sauerkraut during fermentation and storage. The results revealed that pH of the sauerkraut brine ranged between 3.0 and 4.0 and showed a decreasing trend from the day of preparation up to 120th day of storage. The total acidity expressed as per cent lactic acid of sauerkraut ranged between 0.045 and 1.70 and showed an increasing trend from the day of preparation up to 120th day of storage. Ogunjobi *et al.* (2005) studied microflora and proximate analysis of Irish Potato slices fermented in 2.0% brine solution under micro-aerophilic condition for few days at room temperature. The nutritive qualities of the brined-fermented samples were analyzed. There was an increase in microbial load of the brined-fermented samples especially within the first three days of fermentation. Decrease in microbial counts at the later stages of fermentation was attributed to the high total acidity of the medium with reduction in pH from 7.50 to 5.03, while the lactic acid bacteria increased continuously throughout the period of fermentation. The results of the proximate analysis showed that there was a reduction in the crude fiber content from 28.96 to 20.04 mg/g, reducing sugar from 127 to 72 mg/g and ash content from 8.01 to 4.08 mg/g.

CONCLUSION

As most of the vegetables has short self-life so it face a considerable amount of post-harvest losses. To minimize this loss, the fermentation method of preservation an important tool. Different fermented products may be prepared from vegetable like vegetable pickle, sauerkraut, yoghurt etc. But the quality and acceptability of the product depend on the different factor like temperature, microbial strain, humidity, salt concentration etc. Fermentative method of preservation is much cheaper than many of the others preservation technique. Considering all the factor, and necessity it seems that preservation by fermentative method may become more popular in future for vegetable preservation.

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